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CALIBRATION LAB

INSTRUCTION MANUAL
FOR

TYPE TO 7A

TERA-OHMMETER®

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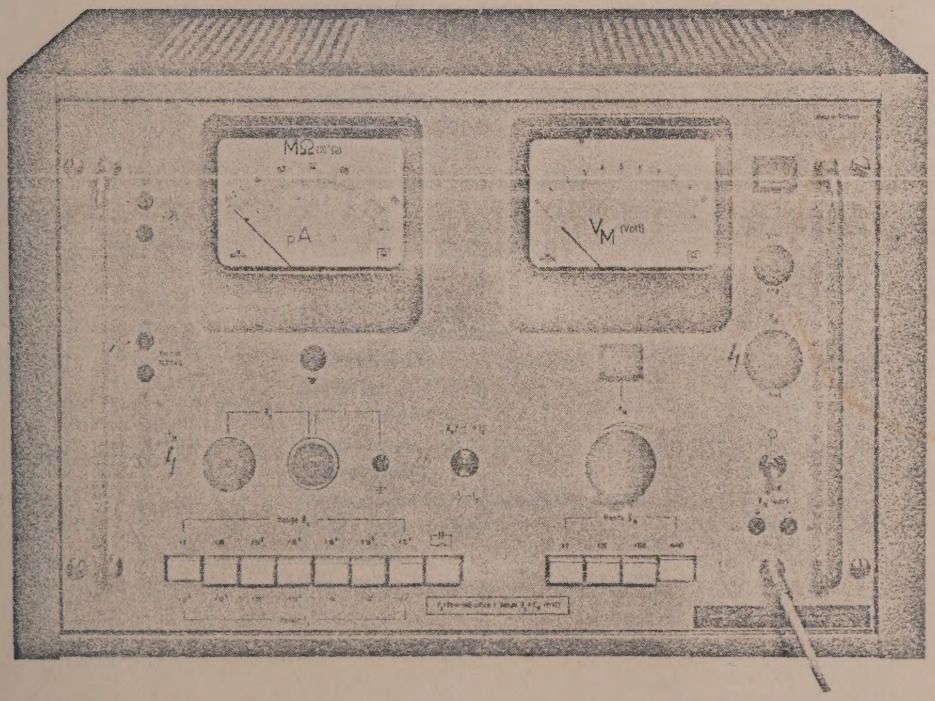

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SECTION I
GENERAL INFORMATION

1-1 GENERAL DESCRIPTION

The Model TO7A is a general purpose Tera - Ohmmeter® for measuring resistance and leakage current. It is unique in offering an extremely wide resistance and current measuring range, at accurate test voltages which can be continuously varied from 0 - 1000 Vdc.

Other important features include high measuring speed, high stability, recorder output, external battery provision, and a means for rapid charge and discharge of test samples.

1 - 2 POWER LINE VOLTAGE

The instrument has been shipped connected for 110 Vac line power. For other line voltages, rotate the selector switch, located on the rear of the instrument, for the desired voltage.

1 - 3 DAMAGE IN TRANSIT

This instrument should be thoroughly inspected when it is received. It has been carefully packed by us at the time of shipment. If any damage is evident, a claim should be filed by you with the carrier. Be certain to retain the shipping case for inspection by the carrier's agent. A full report of the damage should be sent to us or your local R/S representative. We shall then advise you of the disposition of the equipment and will arrange for repair or replacement.

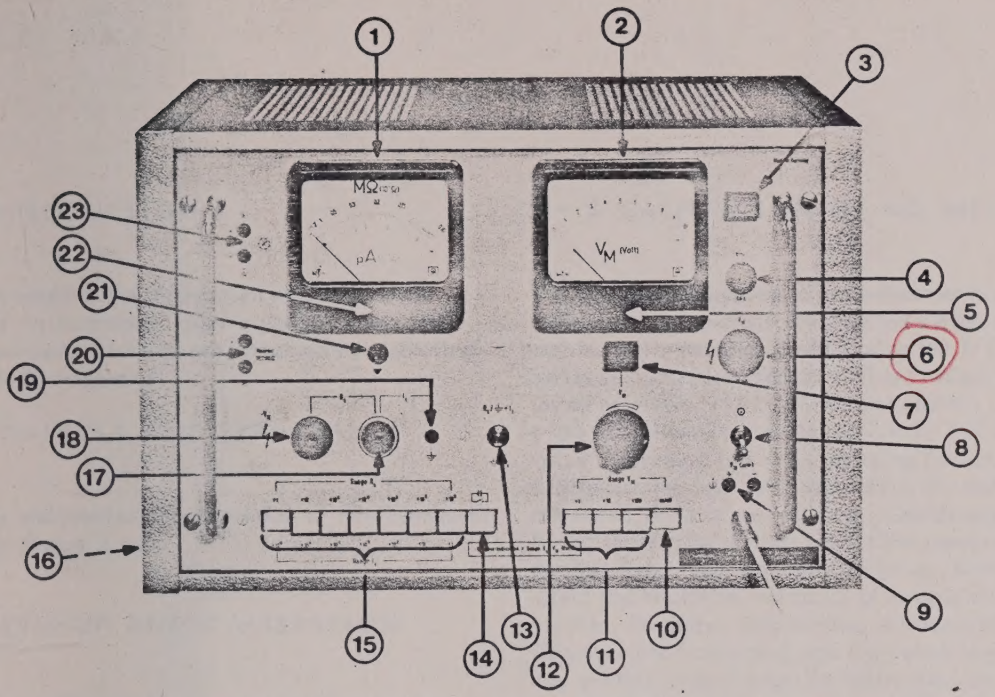
1-4 HIGH VOLTAGE WARNING

This instrument supplies up to 1000 Vdc at the test sample terminals. Though the TO7A is a high impedance device and available current is quite low and not dangerous, always switch the test voltage OFF and discharge the test sample before touching the connections.
BE CAREFUL.

1 - 5 SPECIFICATIONS

Complete specifications for the Type TO7A Tera-Ohmmeter® are presented in the following data sheet. On units starting with Serial Number 34246, the Ⓐ test voltage supply has been changed to 180 Vdc.

OPERATING CONTROLS



1. MΩ and pA meter
2. Test voltage meter
3. Line voltage indicator lamp
4. Line voltage fuse
5. Test voltage meter mechanical zero
6. Test voltage fuse
7. Test voltage ON lamp
8. Line power switch
9. External test voltage input
10. Test voltage ON/OFF switch
11. Test voltage range switch
12. Test voltage level control
13. I_x polarity switch
14. Fast Charge/ Discharge Switch
15. Range switch for R_x / I_x multipliers
16. MΩ meter calibration control
17. R_x low connection ; I_x high connection
18. R_x high connection
19. R_x ground connection ; I_x low connection
20. Recorder output
21. MΩ meter electrical zero
22. MΩ meter mechanical zero
23. Auxiliary meter output

FIG. 2-1

SECTION II
OPERATING INSTRUCTIONS

2 - 1 INTRODUCTION

This section contains the information required for the operation of the instrument. Also a number of test hints and recommended procedures are presented for measuring extremely high resistance.

2 - 2 CONTROLS AND TERMINALS

The controls and terminals for operation of this instrument are shown in Figure 2 - 1.

2 - 3 WARM-UP AND CALIBRATION

Before either calibrating the instrument or making measurements, it should be warmed-up for a period of at least 10 minutes.

2 - 4 METER MOVEMENT MECHANICAL ZERO ADJUSTMENT

Whenever the meter pointers do not indicate exactly the zero position (∞ on MΩ scale), with the instrument line power OFF, they should be reset to zero. For the most accurate positioning, wait until the power has been OFF for at least 1 minute to allow the capacitors in the instrument to discharge. Then rotate the meter mechanical zero adjusting screw clockwise until the meter pointer is travelling toward the left and stop at zero. If you overshoot, continue rotating the adjustment screw clockwise and again approach zero from the right side of the scale. The adjustment screw should never be turned counter - clockwise during any part of this procedure.

2 - 5 CALIBRATION OF MΩ METER

The absolute calibration of the instrument has been set at the factory but should be checked periodically. This may be easily accomplished by using the R/S Type CR Series of Comparison Resistors. These resistors are adjusted to within ± 10 % of nominal and are supplied with a R/S Certificate traceable to N.B.S. The certified value is accurate to ± 1 %. By using the Comparison Resistors as the test item, and setting the test voltage to the stated value appearing on the Certificate, adjust P - 5, located on the left side of the instrument, so that the MΩ meter reads the certified value. Many factors affect the insulation resistance of materials such as: impurities, humidity, temperature, surface conditions, etc. Consequently from one day to the next a specific sample may exhibit large changes in resistance. Use of Comparison Resistors provides an easy means for verifying the performance of the measuring instrument.

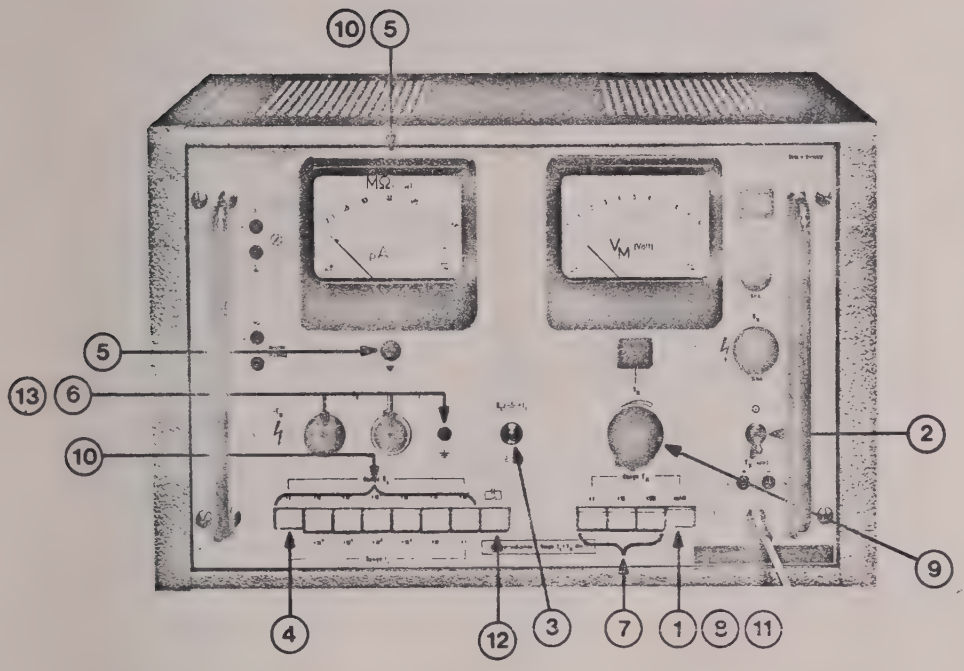
2 - 6 OPERATING INSTRUCTIONS

Necessary instructions for operation of the Type TO7A are illustrated in Figures 2-2 and 2-3.

2 - 7 METHODS OF CONNECTION PICK-UP AND GROUNDING PRECAUTIONS

When measuring small objects, the device can be held to the test sockets of the TO7A by using alligator clips or the Type B1003 Component Test Clips. However, for connecting to large test objects and test fixtures, shielded cables should be used. Use of the R/S Type SC Series of Shielded Cables avoids pick-up and grounding problems. The shields of these cables are connected to the guard terminal of the TO7A, thereby eliminating effects of cable insulation. Test items with metallic parts should be connected so that the minimum possible metallic surface is connected to the center terminal.

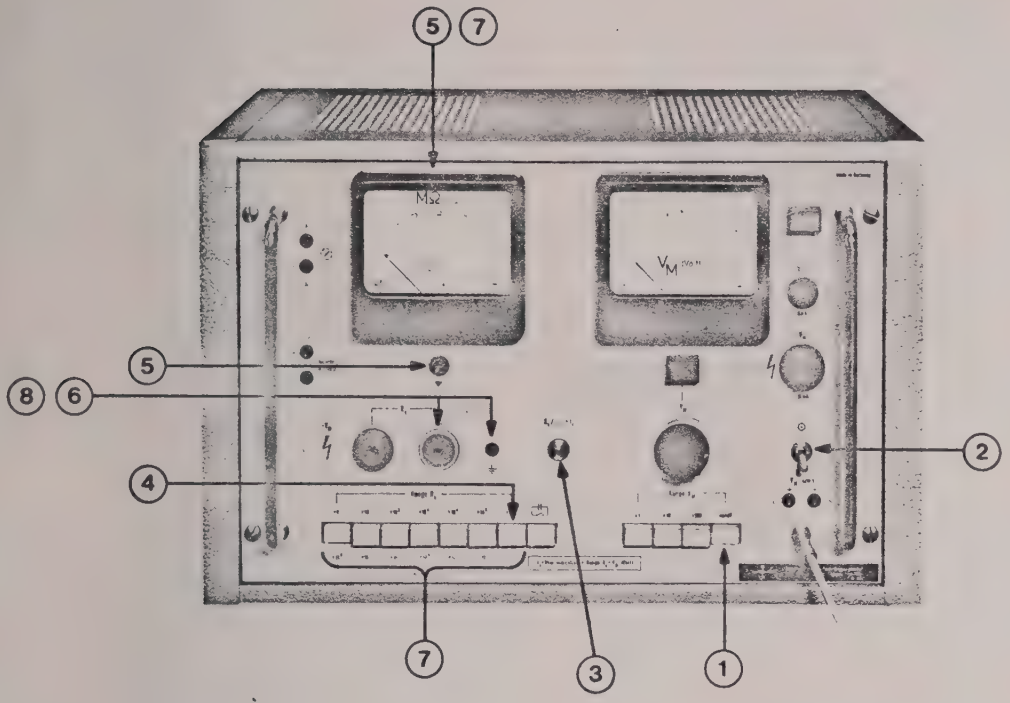
MEASUREMENT OF INSULATION RESISTANCE AND LEAKAGE CURRENT



1. Turn test voltage V_m to OFF (switch out)
2. Turn line power ON and allow 10 minute warm-up.
3. Set to $R_x/\frac{1}{\div} + I_x$
4. Depress Range R_x X 1 switch
5. Adjust pointer to ∞ on MΩ scale
6. Connect test sample to high and low potential test sockets. If test sample is shielded or when using shielded test fixtures, shield is connected to ground.
7. Depress for desired test voltage range.
8. Turn test voltage V_m to ON (switch in)
9. Adjust for desired test voltage level; as read on V_m meter.
10. Depress appropriate Range R_x switch for a resistance reading between 0.1 and 1.0. Insulation current can be simultaneously read using lower scale.
    R_x = MΩ (reading) x R_x (range multiplier) x V_m
    I_x = pA (reading) x I_x (range multiplier)
11. Release to turn test voltage to OFF (switch out).
12. Depress and hold to discharge test item.
13. Disconnect test item.

FIG. 2-2

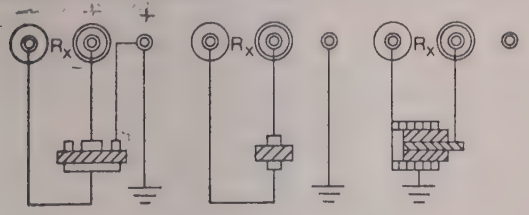
MEASUREMENT OF LOW LEVEL DC CURRENTS



1. Turn test voltage V_m to OFF (switch out)
2. Turn line power ON and allow 10 minute warm-up
3. Set for correct polarity of current.
4. Depress Range I_x X 1 switch.
5. Adjust pointer to "0" on pA scale.
6. Connect current path from active circuit between the shielded input connector and ground.
7. Depress appropriate Range I_x switch for a current reading between 1.0 and 10.0 pA.
   I_x = pA (reading) x I_x (range multiplier)
8. Disconnect active circuit after completion of measurements.

FIG. 2-3

The Tera-Ohmmeter is ideally suited for two terminal and three terminal (guarded) measurements. The red jack is the high test voltage output; the translucent polystyrene jack in the center is the input to the detector; and the terminal to the right is signal ground. In three terminal measurements, the guard should be connected to the ground jack. The cables supplied for use with the R/S sample holders automatically provide the proper connection when the dot or star on the connector spacer is facing upward. In two terminal measurements, the test sample is connected between the red jack and the center terminal.



Guard Ring Non-grounded Grounded

In testing foil wound capacitors, less stray capacitance will generally be found if the outer foil is connected to the red jack, as this will provide a partial shield for the connection to the center jack. When testing polarized components, the test polarity must be observed. In these cases, the negative polarized terminal is connected to the red jack. If motion of an object or the hand in front of the instrument influences the meter indication, especially in the highest measuring range, then shielding of the test sample is recommended. A simple Faraday Cage connected to the ground of the instrument and placed around the test item will suffice. This may be constructed from perforated aluminum sheet metal or ordinary copper window screen, either free-standing or supported by a suitable frame. Either of these methods provides good visibility for most purposes. A test lead should be well bonded to the shield and connected to the ground terminal of the TO7A through a banana type plug. Such a unit is available from R/S under the Part Number B 1006 Shielded Enclosure.

2 - 8 TEST FIXTURES

For insulation measurements of materials there are a large number of sample holders to provide for the precision measurement of volume resistivity. Complete specifications are available from your local R/S Representative.

Type	Description
KMT	Guard Ring Solid Test Fixture
902-820-01	Holder for Insulating Foils
KMD	Wire Test Fixture
KMF	Liquid Test Fixture - 40 cc
KMFG	Liquid Test Fixture - 450 cc
902-800-01	Liquid Test Fixture - 250 cc

2 - 9 RECORDER OUTPUT

The recorder output of the Type TO7A provides a linear DC voltage proportional to the MΩ meter deflection. It has a 1 V output for full scale deflection with a source impedance of 10 kΩ. Any high impedance recorder, e.g. R/S Type ZSG, can be connected to plot data. Since the recorder output is linear, this corresponds to current and linear recording paper should be used. To record directly in ohms, then a special recording paper calibrated in ohms (a reciprocal scale) must be used. Most recorders contain zero-set and full scale or span controls. However if these adjusting controls are not present in the recorder, such controls are located inside the TO7A. The potentiometer, "▽0 Rec" located on printed circuit board, left side rear of the instrument, as viewed from the front can be adjusted to set the recorder zero; and "▽1 V Rec", mounted near the MΩ meter terminals, is used to adjust the full scale span.

2 - 10 AUXILARY METER OUTPUT

An input is supplied which permits the use of an external meter or detector having an equivalent impedance of 1 kΩ and a sensitivity of 250 μA. Such an auxiliary meter is available from R/S, mounted in a slope front cabinet, with extension cable under the Part Number B 1007.

2 - 11 TEST VOLTAGE POWER SUPPLIES

Type TO7A contains two internal power supplies which provide the voltage across the test sample. Battery supply (A) which has a stability of 1 ppm (10^{-6}) consists of two 90 V batteries (Burgess Type V 60 or equal) which are connected in series. This supply provides a test voltage range of 0 - 100 Vdc to the test object. The life of these batteries under normal instrument usage is approximately six months. When it is no longer possible to reach full scale deflection on the V_m meter in the X 10 range position, the batteries should be replaced. When the line power is OFF, a relay opens the battery circuit to prevent accidental drain. Early series of the TO7A use a single battery of 110 Vdc with a life expectancy of about three months. For information on the field modification kit to convert to the newer 90 V battery system, contact your local R/S Representative.

Supply (B) is an electronic supply providing a maximum output of 1000 Vdc. The stability of this supply is about 100 ppm, (10^{-4}). Insulation tests on large capacitors (above 1000 pF) generally require a stability of 1 ppm or better to insure a continuous and smooth charging process. Therefore only the (A) supply should be used which provides a test voltage range of 0 - 100 Vdc. For measurements on large capacitors at test voltages from 100 - 1000 Vdc, it is necessary to use an external battery supply. R/S Type B 1005 Battery Power Supply provides a compact source.

When the external supply is connected to the "V_m EXT" input, observing the correct polarity, the electronic supply is automatically disconnected. When the "X 100" Test Voltage multiplier is depressed and the test voltage "ON/OFF" switch is turned ON, the external supply is connected in series to the internal battery supply Ⓐ. The test voltage meter then indicates the total voltage applied to the test sample. The test voltage level control may be used to adjust the test voltage to the desired test level between 180 - 1000 Vdc.

WARNING

When the external battery supply is used, care should be taken to make the connections between battery box and Type TO7A by means of banana plugs at least 21mm in length. Shorter plugs will not operate the switch that disconnects the internal battery supply. The connecting cable supplied with the B 1005 Battery Supply uses plugs which are this length and is also marked for the correct polarity.

SECTION III
THEORY OF OPERATION

- 1 INTRODUCTION

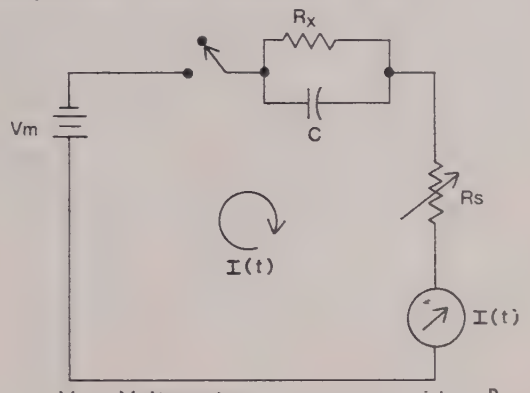
Only a few years ago, insulation resistances of a few hundred or possibly a few thousand megohms were considered satisfactory and could be measured with relatively simple instrumentation. The requirements of today's electronics, and in particular, the development of new insulating materials, such as polyethylene, teflon, etc. call for instruments with far wider ranges and capabilities and greater flexibility. This requirement is met by the Type TO7A Tera-Ohmmeter® which makes it possible to measure from 100 kΩ to 10,000 TΩ. Owing to recent developments in semiconductors, of the FET transistor and associated components, e.g. sockets etc., there is need for high insulation measurements at very low voltages. Accordingly, the Type TO7A provides a continuously variable test voltage from 0 - 1000 Vdc. Since the instrument is also calibrated in terms of current, voltage vs. current characteristics of semiconductors can be easily measured and recorded.

Unlike high resistance bridges, which generally require frequent readjustment to null, the Type TO7A is a direct reading measuring instrument which instantaneously indicates changes in insulation resistance and current as a function of time, environmental changes, and also actual physical changes within the test material. This is an important advantage since resistance of most material is seriously affected by variations in temperature, humidity, voltage, pressure, etc. Consequently the slope of the resistance curve, dR/dt, may be of more interest than its final value. Such qualitative information can be obtained by observing the deflection of the MΩ meter pointer. For example, under conditions of potential stress (resulting from ion avalanches), partial or complete breakdown (rupture) of the sample, the operator will observe erratic pointer deflection. Note that even in the case of a complete short circuit, the Type TO7A cannot be damaged.

Moreover, Type TO7A can be used as a conventional picoammeter, measuring low level currents from active circuits. The test voltage supply of the instrument is not utilized in this mode of operation.

3 - 2 THEORY OF OPERATION

Measurement of insulation resistance and leakage current of dielectrics of homogeneous structure is represented by the equivalent circuit illustrated in Figure 3 - 1.



V_s = Voltage drop across range resistor, R_s
V_m = Applied test voltage at $t = 0$
R_x = Insulation resistance of test object
C = Capacitance of test object, cables, and input capacitance of TO7A
R_s = Range resistor of TO7A ($10^3 - 10^9\ \Omega$)

Assuming that $R_x \gg R_s$ (which holds true for TO7A), then equation 3 - 1 represents the approximate current - time relationship:

$$I(t) = \frac{V_s}{R_x}\left[\frac{R_x}{R_s}\, e^{-t/T} + 1\right] \qquad (3-1)$$

where $T = R_s C$ (3 - 2)

The steady-state value of (3 - 1) then becomes:

$$I_{ss} = \frac{V_s}{R_x} \qquad (3-3)$$

The steady - state dc current is read on the MΩ meter which has a logarithmic scale calibrated in terms of $1/R_x$.

In the Type TO7A the maximum ratio of R_x / R_s is: $10^{16} / 10^9 = 10^7$ and it can be determined that the longest measuring time is:

$$t_{max} \text{ (secs)} = 20\, R_s\, C = 20\, T \qquad (3-4)$$

The actual time required for the measurement is determined by the number of time constants (T) neccessary for:

$$\frac{R_x}{R_s}\, e^{-t/T} < 3\ \% \qquad (3-5)$$

Table 3 - 1 presents R_s as a function of measuring range.

TABLE 3 - 1

Measuring Range MΩ	x 1	x 10	x 10^2	x 10^3	x 10^4	x 10^5	x 10^6	Chg.
R_s (Ω)	10^3	10^4	10^5	10^6	10^7	10^8	10^9	10^4

For measuring high resistances of large capacitors, it can be seen that the time constant, T , (see Eq. 3 - 2) can become quite large. To speed up the charging time, provisions have been made in the Type TO7A for rapid charge/discharge of capacitors using the push button switch 14 (see Figure 2 - 1) located on the front panel. Use of this feature establishes $R_s = 10^4\ \Omega$. In certain cases where $R_s C$ is very large, it may be neccessary to pre-charge capacitors from an external battery supply.

Consider the following example of measurement of a capacitor of 10 μF with insulation resistance of $2\,(10^{10})\ \Omega$, and being tested at 100 Vdc. Since the resistance, R_x , is:

$$R_x = \text{MΩ (meter reading)} \times R_x' \text{ (range mult.)} \times V_m$$

we have:

$$R_x' = \frac{R_x}{\text{MΩ(reading)} \times V_m} \qquad (3-6)$$

$$= \frac{2\,(10^{10})}{0.2\,(10^6)\,(100)}$$

$$R_x' = X\,10^3$$

Using $X\,10^3$ we would have $R_s = 10^6\ \Omega$. To speed up the process of charging we shall use the charge/ discharge button which will make $R_s = 10^4\ \Omega$. To determine the measuring time we must satisfy Eq. 3 - 5

$$\frac{R_x}{R_s}\, e^{-t/T} < 3\ \%$$

$$\frac{2(10^{10})}{10^4}\, e^{-t/T} < 3\ \%$$

Solving this expression we obtain $t = 18\ T$ or the measuring time is: $t = 1.8$ secs.
After the charge button has been depressed for approximately two seconds, the capacitor will be charged. Then release the charge button and read the insulation resistance.

Measurements on insulating materials in practice show characteristic deviations from the calculated results because of their inhomogeneous structure. When the insulating material consists of layers of substances with different conductivities, different dielectric absorption, and dielectric constants, additional charging currents can occur. Reaching the final condition is delayed by a complicated process of charges and discharges which can occur rather slowly. Depending on the type of insulating material, changes in the measured value can still be observed after several minutes, and in the case of certain synthetic insulating materials, even after several hours. In certain capacitors, using synthetic materials, small polarization voltages occur in addition, which are in opposite polarity to the measuring voltage. The insulation resistance of such capacitors must therefore be measured more rapidly and before these effects take place.

When the final condition is approached, the polarization voltage makes it appear as if the insulation resistance increased slowly to ∞ and finally reached negative values.

When the additional charge is completed it is no longer the insulation resistance, but the polarization voltage across the input resistance of the instrument which is being measured. The internal resistance of the polarization voltage source is in the order of several megohms. The polarization voltage gives an end deflection of between 0 - 10 mV. This explains why the deflection remains nearly the same when one switches to the most sensitive ranges of the instrument. The indication of negative resistance values is a criterion for the test object being an active two terminal device which produces a voltage which bucks the applied test voltage.

In addition to the charging current, there is also the effect of the surface current which characterizes the surface resistance. If the insulating material is, for instance, hygroscopic, then the surface resistance may be greatly reduced by the presence of moisture. The same is true for extremely fine cracks and tears in the surface in which dirt and humidity can gather. The surface resistance is measured between two knife edge electrodes.

The guard-electrode principle is also suitable. In the insulating material a current flows which consists of four main components which are time-dependent. These components are the current flowing through the volume,

the current flowing across the surface, the capacitive displacement current, and the additional charging current. If polarization voltages occur, their effect must also be taken into account. The insulation resistance changes also with the duration of the measurement by the effect of heat, humidity and chemicals, through the influence of mechanical stress, through the previous history of the material, and with the level of the applied test voltage. Sometimes the effect of illumination and radioactive radiation can be observed. Reproducible measured values of the insulation resistance can therefore only be obtained when the condition of the insulating material is accurately defined.

3 - 4 BEHAVIOR OF A DIELECTRIC UNDER UNDER D.C. POTENTIAL

Whenever a voltage is applied to a dielectric (an insulating material), a minute current flows. As the voltage stress is increased, the conduction increases and the resistance decreases. This value of resistance is not usually constant: it increases gradually with the time of electrification to a limiting value for that voltage stress. This phenomenon is called dielectric absorption. It may take weeks, months, or years to reach the limiting value. An increase in temperature causes an exponential decrease in resistance. When the log of the resistance (vertical axis) is plotted vs. the reciprocal of the absolute temperature (horizontal axis), a straight line is usually found for small changes in temperature. Curvature and inflection points indicate either changes in the material (e.g. crystal melting) or in the predominating method by which the charges are transported in the material. Because of the slowness of these changes in the structure of dielectric materials, sharp inflection points are usually difficult to find and plotting of curves generally becomes neccessary.

The absorption of moisture lowers resistance. For small percentages of absorbed moisture, the decrease in resistance (log R) is almost a straight line but decreases more and more rapidly until a sudden decrease of many decades occurs and then begins to level off. This catastrophic decrease is usually caused by ionic conduction becoming the predominant mode of conduction. The point at which this change in conduction occurs is determined for a given material by many factors, especially molecular polarity, dielectric constant, and purity. Some dielectrics cannot absorb enough moisture to ever reach this point, while others will reach it only if other factors such as temperature and pressure are correct.

3 - 5 MEASUREMENT OF RESIDUAL CURRENTS OF TRANSISTORS

Residual currents of transistors can easily be measured with the Type TO7A. If the collector-base residual current, I_{cbo}, is to be measured as a function of the collector-base bias voltage, V_{cbo}, for instance, then the emitter remains open-circuited. For NPN transistors the base is connected to the red terminal of the TO7A and the collector is connected to the center jack. For PNP types of transistors, the connections are reversed. After applying the correct bias voltage, the current can be measured in the range of 0.1 pA to 10 μA. If the transistor is placed in a temperature controlled oven, then the current vs. temperature relationship can be determined. The Type B 1004 is a convenient sample holder for use with semiconductors for this measurement.

3 - 6 MEASUREMENTS IN ACCORDANCE WITH ASTM SPECIFICATIONS

Definitions and Derivations

Volume Resistance: (R) --- The volume resistance between two electrodes which are in contact with, or embedded in a specimen, is the quotient obtained when the direct voltage applied to the electrodes is derived by that portion of the current between them that is distributed through the volume of the specimen.

Surface Resistance: (R) --- The surface resistance between two electrodes which are on the surface of a specimen is the quotient obtained when the direct voltage applied to the electrodes is divided by that portion of the current between them which is a thin layer on the surface.

Volume Resistivity: (ρ) --- The volume resistivity of a material is the quotient obtained when the potential gradient parallel to the direction of the current flow in the material is divided by the current density. Note: In the metric system of measurement, the volume resistivity of a material in ohm-cm is equal to the volume resistance between opposite faces of a cm cube of the material.

Surface Resistivity: (σ) --- The surface resistivity of a material is the quotient obtained when the potential gradient parallel to the direction of the current flow along its surface is divided by the current per unit width of surface. Note: Surface resistivity of a material is equal to the surface resistance between two electrodes forming opposite sides of a square. The size of the square, circle, or cylinder is immaterial.

The volume resistivity is calculated from the measured resistance and a knowledge of the specimen dimensions. The resistance of a homogeneous and isotropic material varies directly with its length (d) and inversely with its cross-sectional area (A) as:

$$R \propto \frac{d}{A}$$

By inserting a proportionality constant (ρ) and solving we then have the equation for volume resistivity:

$$\rho = \frac{RA}{d} \qquad (3-7)$$

The units chosen may be in any consistent system desired. The units most commonly reported are ohms and centimeters; this gives us volume resistivity in:

$$\frac{\text{ohm} \quad \text{cm}^2}{\text{cm}} = \text{ohm} \quad \text{cm}$$

For convenience in describing wire and cable, a circle of 1/1000 inch diameter is used as the standard unit of area and the length is given in feet. The measured values are therefore referred to as resistance per circular mil foot.

Surface Resistivity:

The resistance across the surface of a material varies directly with the length of the path (g) and inversely with its width (P).

$$R \propto g/P$$

Inserting the proportionality constant (σ) defined as surface resistivity, we have:

$$R = \sigma \frac{g}{P}$$

or Surface Resistivity = $\dfrac{R\,P}{g}$ $\qquad (3-8)$

It is interesting to note that, unlike volume resistivity, surface resistivity is independent of length. This gives us:

$$\frac{\text{ohm} \quad \text{cm}}{\text{cm}} = \text{ohms}$$

When it is not possible or practical to know the specimen dimensions, the volume resistivity may be calculated by substituting 11.3 C for the specimen dimensions, where C is the low frequency capacitance of the electrodes with air as the dielectric.

$$\text{Volume Resistivity} = 11.3\ C\ (\text{pF})\ R\ (\Omega)$$

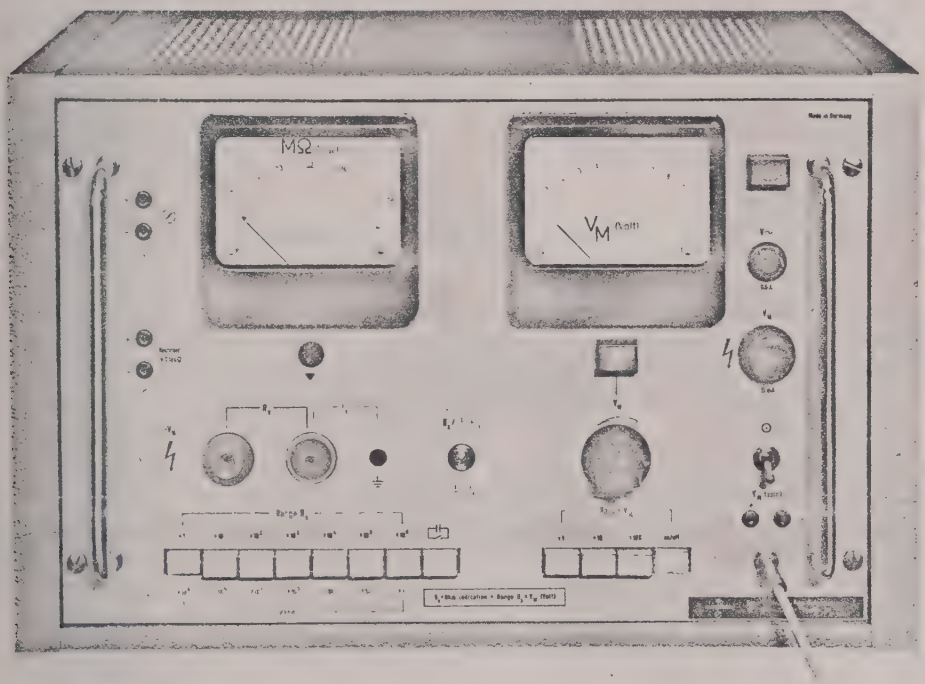
3 - 7 ELECTRODES

A general summary of a wide variety of electrode types and forms is given in ASTM Method D-257. In addition, each material specification generally stipulates the particular electrodes to be used and the precise test conditions in order that measured values will be comparable between laboratories.

The most common electrodes for testing solid and liquid dielectrics are available as accessories for use with the Type TO7A. Specifications for both liquid and solid sample holders appear in the data sheet for the Type TO7A.

TYPE TO 7A

TERA-OHMMETER®



- **RESISTANCE RANGE**
  100 kΩ to 10,000 TΩ (10^5 to $10^{16}\Omega$)
- **CURRENT RANGE**
  0.1 pA to 10 μA (10^{-13} to 10^{-5} A)
- **TEST VOLTAGE**
  0 to 10, 100, 1000 VDC, Continuously Variable
- **MEASURES IN ACCORDANCE WITH ASTM D-257 & IEC 93**
- **HIGH SPEED**
  Measures in Seconds
- **HIGH ACCURACY**
  ±3%, ±1% with Type CR Comparison Resistors
- **ALL SILICON SOLID STATE DESIGN**
- **RECORDER OUTPUT**

ROHDE & SCHWARZ
111 LEXINGTON AVENUE • PASSAIC, NEW JERSEY 07055 • (201) 773-8010

APPLICATIONS

Type TO 7A Tera-Ohmmeter® offers highly accurate resistance and leakage current measurements. It provides the ideal instrument for the analysis of the many factors affecting insulation resistance such as: humidity, temperature, impurities, voltage coefficient, surface conditions, etc. The Tera-Ohmmeter finds unlimited application in both R&D and production use. It is unique in offering an extremely wide resistance and current measuring range, at accurate test voltages which can be continuously varied from 1-1000 V. Other features include high measuring speed, high stability, recorder output, and provision of charge and discharge of test sample.

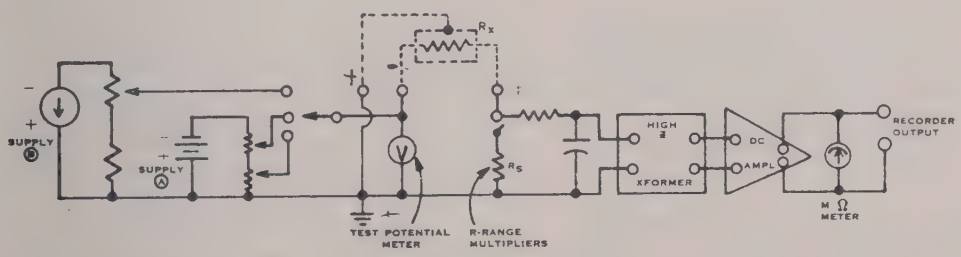
- Measure Insulation Resistance and Leakage Current of Components, including: Capacitors, Transformers, Switches, Cables, Wires, Pots, etc.

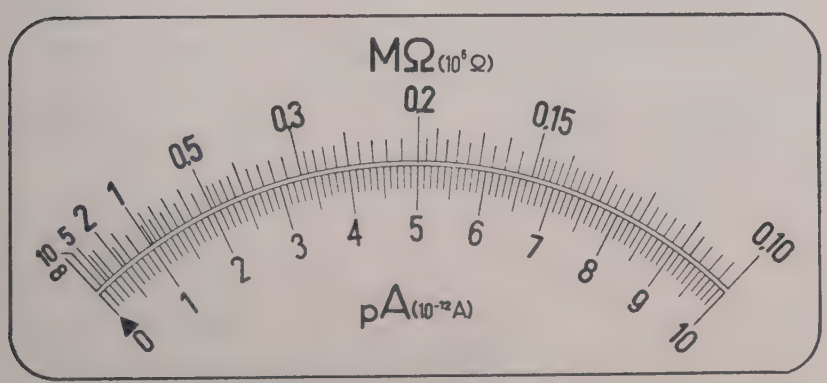
  Insulating Materials and Lacquers, including: plastics, glass, rubber, oils, varnishes, mica, papers, etc.
- Semiconductors — measure residual currents vs. voltage & temperature.
- Determine Volume and Surface Resistivity
- Measure Voltage Coefficients
- Measure Purity of Liquids

TECHNICAL DESCRIPTION

The test voltage applied to the sample is controlled by the Voltage Range Multiplier and a continuously variable level control, which is measured by meter V. The Voltage Range Multiplier selects output of the corresponding power supply (A or B). The level control consists of a three-gang potentiometer which determines the voltage divider ratio in each supply. With the test voltage impressed across the test sample, R_x, a leakage current flows through R_x and the selected range resistor, R_s. Since $R_s \ll R_x$ (maximum $R_s = 10^9\Omega$) the voltage drop (V_x) across R_s is approximately 1 mV. This voltage is applied to the input of an active high impedance DC transformer with negligible drift and whose output drives a low impedance, high stability, DC amplifier. The output of the amplifier drives the MΩ-meter movement and also provides the recorder output.

Since the transformer and the amplifier are extremely linear, and since $R_s \ll R_x$, V_x is inversely proportional to R_x. This eliminates individual calibration of meter scales and permits simultaneous current measurements. A second linear scale is calibrated in pA. A high resolution meter scale is provided to be commensurate with the high accuracy (±3%) of the instrument. The meter scales are shown below.





RESISTANCE / CURRENT
Measuring Scale

SPECIFICATIONS

RESISTANCE MEASUREMENTS:

Range: 100 kΩ to 10,000 TΩ (10^5 to $10^{16}\Omega$)

Readout: DC meter with anti-parallax knife-edge pointer, calibrated in 66 divisions ($\frac{1}{1}$ scale) from 0.1 to 10 MΩ (∞), with 100 mm scale length

Multiplier: Six push buttons from "X1" to "$X10^6$"

Resistance (R_x) = (MΩ reading) X (R Multiplier) X (V Reading) X (V Multiplier)

Accuracy: ±3% of reading for meter deflections between 0.1 and 1.0 after initial calibration

Time of Measurement: Dependent on capacitance of test sample — usually a few seconds

TEST VOLTAGE:

Range: 0 to 1000 VDC, utilizing two power supplies: Ⓐ 110 V battery, and Ⓑ 1000 V electronic supply. A provision for "external" batteries is made.

Multiplier: Three push button switches "X1, X10, X100" and separate "ON/OFF" switch.

MULTIPLIER	TEST VOLTAGE	POWER SUPPLY
x 1	0 - 10 VDC	Ⓐ
x 10	11 - 100 VDC	Ⓐ
x 100	110 - 1000 VDC	Ⓑ

Readout: DC meter with anti-parallax knife-edge pointer, calibrated in 100 linear divisions from 0 to 10 V with 100 mm scale length

CURRENT MEASUREMENTS:

Range: 0.1 pA to 10 μA (10^{-13} to 10^{-5} A)

Int. Resistance: From $10^9\Omega$ to $10^3\Omega$

Readout: Uses resistance meter (MΩ). Current scale calibrated in 100 linear divisions from 0 to 10 pA.

Multiplier: Same as resistance multiplier, calibrated "$X10^5$" to "X1"

Current (I_x) = (pA Reading) X (I Multiplier). Polarity switch allows reversal of polarity

Accuracy: ±3% f.s.d. for meter deflections between 1.0 and 10 pA after initial calibration

Speed of Measurement: Approx. 1 second

OPERATING TEMPERATURE:

−10°C to +50°C for ranges "X1" to "$X10^5$"
+10°C to +30°C for range "$X10^6$"

D.C. Drift: ±1% f.s.d. for △ T = 5°C
Warm-up time approx. 10 mins.

OUTPUTS:

Recorder: 1 VDC for f.s.d., 10 kΩ input resistance

Remote Meter: Requires 250 μA f.s.d., with 1000Ω internal resistance

DISCHARGE: Fast charge or discharge of test item by push button switch.

Instrument completely protected against damage from short circuit in test samples. Design is all silicon solid state.

TEST VOLTAGE:

Stability: Supply Ⓐ: 1 ppm (10^{-6})
Supply Ⓑ: 100 ppm (10^{-4})
Note: Insulation tests on capacitors generally require a stability of 1 ppm or better to guarantee a continuous and smooth charging process; therefore, only supply Ⓐ or external batteries should be used.

Accuracy: ±½% f.s.d.

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POWER REQUIREMENTS:

110/125/150/220/240 V rms ±10%, 40-60 Hz, approx. 50 VA

DIMENSIONS: 13½ in. (345 mm) high x 21½ in. (545 mm) wide x 11 in. (280 mm) deep. 19 in. rack model available.

WEIGHT: Approx. 44 lbs. (20 kg) net;
75 lbs. (34 kg) shipping wt.

PRICE: $1380.00 f.o.b. Passaic, N. J.

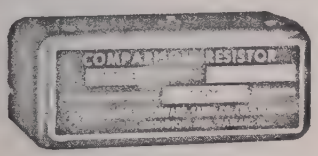
COMPARISON RESISTORS

Type CR Series

Since insulation resistance is affected appreciably by environmental conditions, it is highly desirable to use the R/S Comparison Resistors to verify resistance readings. Each resistor is supplied with a R/S Certificate traceable to N.B.S. stating the resistance value and temperature coefficient. Resistors are adjusted to within ±10% of nominal value and certified to an accuracy of ±1%. The SR Series of Comparison Resistor Sets is available to provide the range of coverage desired.

Comparison Resistors for Tera-Ohmmeters

Model	Value	Price	Model	Value	Price
CR 498	1 MΩ	$35	CR 502	10,000 MΩ	$35
CR 499	10 MΩ	$35	CR 503	100,000 MΩ	$35
CR 500	100 MΩ	$35	CR 504	1 TΩ	$40
CR 501	1000 MΩ	$35	CR 505	10 TΩ	$40
SR Series	Set of Comparison Resistors to be specified by customer. Includes storage, mounting base. Price: Price of individual CR's + $10.				
SR 551	Set of 5 Comparison Resistors: CR 501-505 (does not include mounting base) Fed Stock No. 5905-628-1746 $185.				



SHIELDED CABLES

Type SC Series

To avoid pick-up and grounding problems, it is advantageous to use the Type SC Shielded Cables for connecting sample holders to the measuring instrument. The shields on these cables are connected to the guard terminal of the Tera-Ohmmeter thereby eliminating effects of cable insulation.

Shielded Cables For Tera-Ohmmeter

SC 511	Shielded Cable, 20 in. long	$40
SC 512	Shielded Cable, 40 in. long	$42
SC 513	Shielded Cable, 60 in. long	$44

ACCESSORIES

LIQUID-SPECIMEN CONTAINER

Type KMF (BN 5721/3) $212.

Liquid-specimen volume ..... approx. 40 cc.

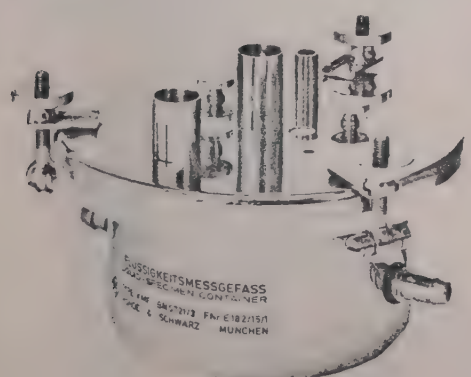
Test capacitance, C_o ..... approx. 35 pF

Spacing between inner and outer containers ..2 mm

Temperature range ..... −40° to +200°C

Frequency range ..... DC to 300 kHz

The specimen container operates on the guard-ring method. Polytetra-fluorethylene insulators separate the individual electrodes. In conjunction with a temperature-controlled circulator, liquid samples can be measured over the temperature range of the KMF.



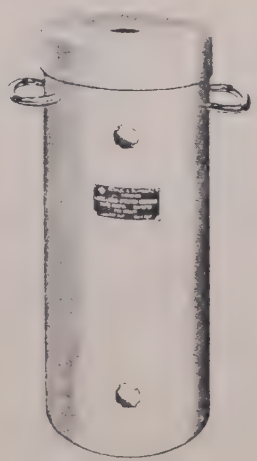
LIQUID-SPECIMEN CONTAINER

Type KMFG (BN 5722) $440.

Liquid-specimen volume ..... approx. 450 cc.

Test Capacitance, C_o ..... approx. 165 pF

The Type KMFG is used to determine the dissipation factor and the dielectric constant of liquids at frequencies to 60 Hz. At these frequencies, a higher sensitivity is insured with this measuring container than is obtainable with a container having a smaller capacitance between the test electrodes.



GUARD-RING CAPACITOR

Type KMT (BN 5711) $780.

ameter of guard-ring protected electrode ..... 80.3 mm

ectrode spacing, adjustable ..... 0 to 10 mm

tting accuracy with micrometer ..... 0.01 mm

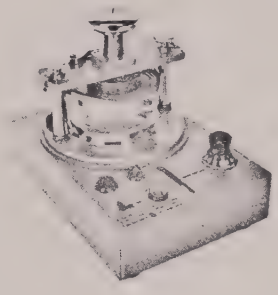
e plates of the capacitor are supported by an uminum casting. The lower of the polished steel ates of the capacitor is stationary and surrounded a guard ring. The upper one can be moved in ial direction by a threaded spindle fitted with a icrometer scale. The heavy-duty spindle enables ils to be tested even under heavy pressure. The sulation consists of ceramic insulating material.

GUARD RING CAPACITOR FOR INSULATING FOILS

L. No. 902-820-01 $1,388.

Diameter of the plates ..... 10.0 cm
Diameter of the test area ..... 8.0 cm
Width of the protective gap ..... 1 mm
Pressure of the plates ..... 10 kg (equivalent to 200 g/cm²)
Maximum foil thickness ..... 5 mm
Temperature range ..... +20° to +120°C
Temperature regulation ..approx. ±1°C after 1 hour
Maximum test voltage ..... 1000 V
Heater power ..... approx. 300W

This test capacitor is used for determining the dissipation factor (tan δ), the resistivity, and the dielectric constant of insulating foils as a function of the temperature.



ACCESSORIES

TEST CAPACITOR FOR USE WITH LIQUIDS

L. No. 902-800-01 $1,133.

apacity ..... approx. 250 cc.

st Capacitance, C_o ..... approx. 380 pF

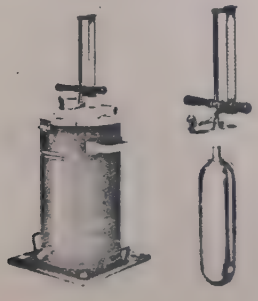
ectrodes ..... nickel-plated brass

ectrode clearance ..... 2 mm

electric strength, empty ..... 5000 V r.m.s.

rmissible temperature range ... −10° to +200°C in conjunction with a temperature controlled circulator

ne capacitor is used for determining the dielectric nstant, dissipation factor (tan δ), and the resistivity of liquids as a function of the temperature.



TEMPERATURE CONTROLLED CIRCULATORS

Available is a system covering from 0° to +240°C which includes the circulator, precision thermometers, ultra-thermostat, pump, and all interconnecting lines .....$695.

Other temperature ranges available.

Prices on request.

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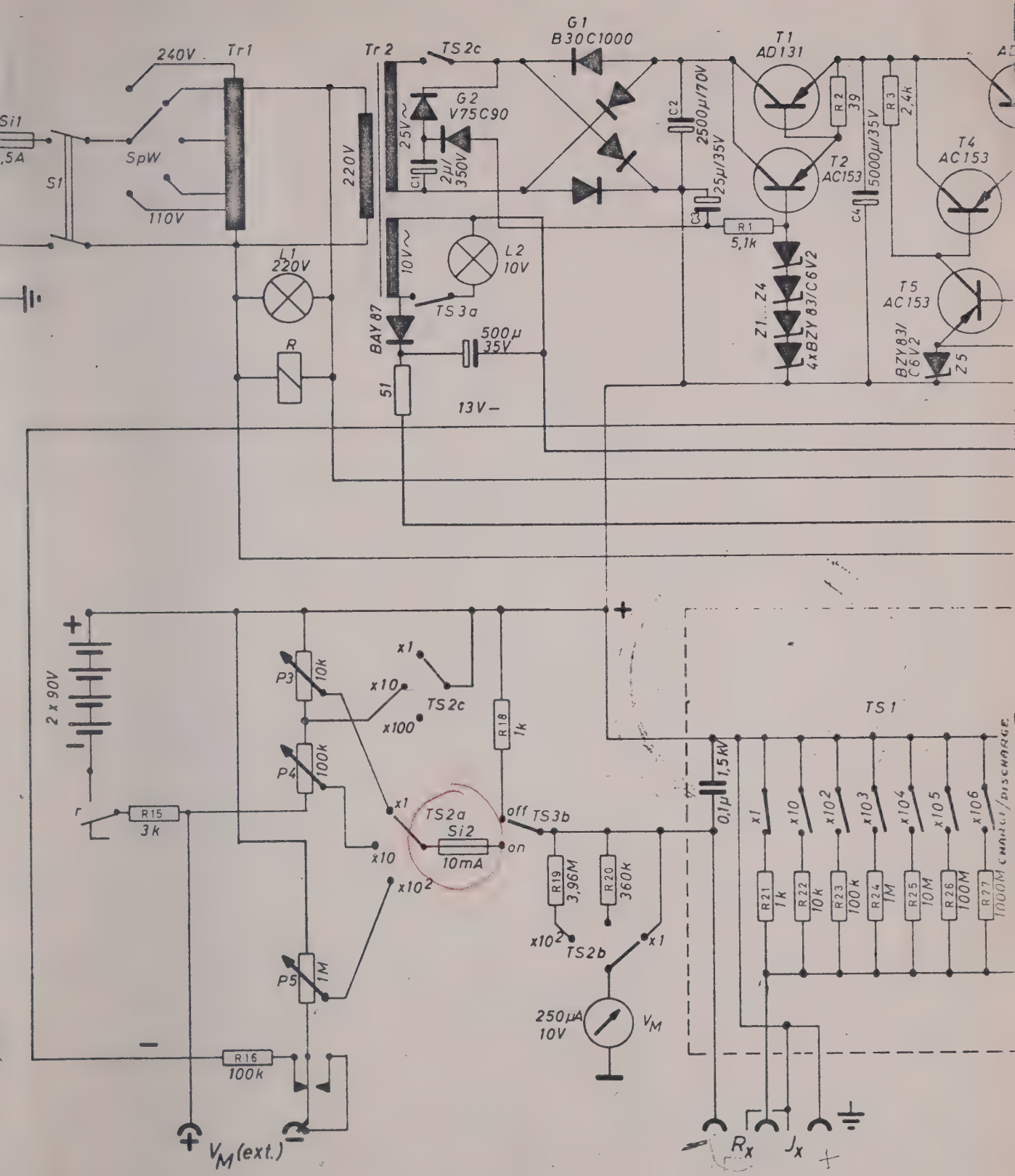
Data and Prices are subject to change without notification.

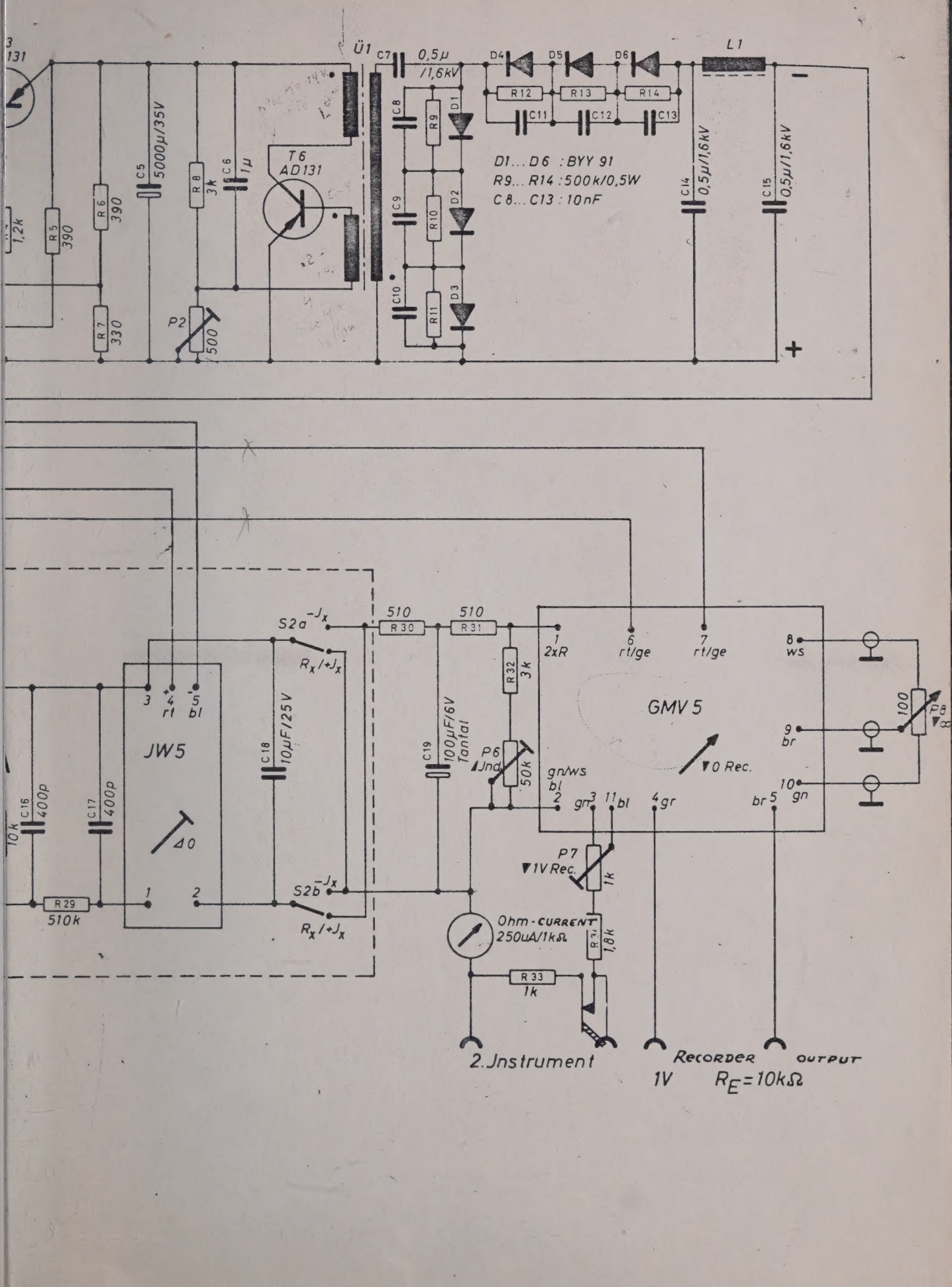


TYPE TO7a

TERA-OHMMETER®

FOR INSULATION MEASUREMENTS

MARCH, 1967


Ü1
C7 0,5µ /1,6kV
L1
D4 D5 D6
R12 R13 R14
C11 C12 C13
D1...D6 : BYY 91
R9...R14 : 500k/0,5W
C8...C13 : 10nF
C14 0,5µ/1,6kV
C15 0,5µ/1,6kV
T6 AD131
C5 5000µ/35V
C6 1µ
R8 3k
R5 390
R6 390
R7 330
P2 500
C8 C9 C10
R9 R10 R11
D1 D2 D3
S2a -Jx
S2b -Jx
Rx/+Jx
Rx/+Jx
510 R30
510 R31
R32 3k
C19 100µF/6V Tantal
P6 Jnd. 50k
C18 10µF/25V
JW5
Δ0
C16 400p
C17 400p
10k
R29 510k
GMV 5
0 Rec.
P7 1V Rec. 1k
R34 1,8k
R33 1k
Ohm-CURRENT 250uA/1kΩ
P8 100
1 2xR
6 rt/ge
7 rt/ge
8 ws
9 br
10 gn
2 gn/ws bl
3 gr
11 bl
4 gr
5 br
3 4 rt 5 bl
1 2
2. Jnstrument
RECORDER OUTPUT
1V R_E=10kΩ